APPLICATION

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TITLE: MULTIBAND ULTRA WIDEBAND COMMUNICATIONS

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MULTIBAND ULTRA WIDEBAND COMMUNICATIONS

Background

This invention is generally relative to multiband ultra wideband communications (UWB) for short-distance wireless broadband communication.

U.S. Federal Communications Commission (FCC) released the revision of Part 15 of the Commission's rules regarding UWB transmission systems to permit the marketing and operation of certain types of new products incorporating UWB technology on April 22, 2002. With appropriate technology, UWB device can operate using spectrum occupied by existing radio service without causing interference, thereby permitting scare spectrum resources to be used more efficiently. UWB technology offers significant benefits for Government, public safety, businesses and consumers under an unlicensed basis of operation spectrum.

In general, FCC is adapting unwanted emission limits for UWB device that are significantly more stringent than those imposed on other Part 15 devices. FCC limits outdoor use of UWB device to handheld devices for short-distance wireless communication. For the indoor operation of communication, FCC provides a wide variety of UWB devices, such as high-speed home and business networking devices under Part 15 of the Commission's rules subject to certain frequency and power limitations. Limiting the frequency bands, which is based on the -10 dB bandwidth of the UWB

emission, within certain UWB products will be permitted to operate. The UWB device must operate in the frequency band from 3.1 GHz to 10.6 GHz. UWB communication devices should satisfy the Part 15.209 limit for the frequency band below 960 MHz and must meet the FCC's emission masks for the frequency band above 960 MHz.

For the indoor UWB communication operation, Table 1 lists the FCC restrictions of the emission masks (dBm) along with the frequencies (GHz).

Table 1

Frequency (MHz)	EIRP (dBm)
0-960	-41.3
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

The outdoor handheld UWB communication systems are intended to operate in a peer-to-peer mode without restriction on location. However, the handheld UWB device must operate in the frequency band from 3.1 GHz to 10.6 GHz, with an extremely conservative out of band emission masks to address interference with other communication devices. The outdoor handheld UWB communication devices are permitted to emit at or below the Part 15.209 limit in the frequency band below 960 MHz. The emissions above 960 MHz

must conform to the following emission masks as shown in Table 2:

Table 2

Frequency (MHz)	EIRP (dBm)
0-960	-41.3
960-1610	-75.3
1610-1900	-63.3
1900-3100	-61.3
3100-10600	-41.3
Above 10600	-61.3

FCC defines a UWB device as any device where the fractional bandwidth is greater than 0.25 based on the formula as follows,

$$FB = 2\left(\frac{f_H - f_L}{f_H + f_L}\right), \qquad (1)$$

where f_H is the upper frequency of the -10 dB emission point and f_L is the lower frequency of the -10 dB emission point. The center frequency of the transmission was defined as the average of the upper and lower -10 dB points. That is

$$F_C = \frac{f_H - f_L}{2}. \qquad (2)$$

In addition, a minimum bandwidth of 500 MHz must be used for indoor and outdoor UWB devices regardless of center frequency.

The UWB communication devices must be designed to ensure that operation can only occur indoor according to

indoor emission masks in Table 1 or it must consist of hand-held devices that may be employed for such activities as peer-to-peer operation according to the outdoor emission masks in Table 2. Such UWB devices can be used for wireless communications, particularly for short-range high-speed data transmissions suitable for broadband access to networks.

UWB communication device is true digital radio communication; completely unlike the conventional radios we listen to and communicate every day. UWB communication device is a wireless broadband communications technology fundamentally. UWB communication device is to transmit a sequence of very short electrical pulses, billionths of a second long, which exist not on any particular frequency but on all frequencies simultaneously. UWB communication device uses modulated pulses with less one nanosecond in duration. The modulated pulse is usually assigned a digital representation of 0 or 1 to the transmitted and received pulse based on where the pulse is place in time. The key of turning the digital pulses into wireless broadband communication lies in the timing of the pulses. In order to hear the information in that code, a UWB radio receiver has to know the exact pulse sequence used by the transmitter.

Each pulse can exist simultaneously across an extensive band of frequencies if the distributed energy of the pulse at any given frequency exists in the noise floor.

Therefore, UWB can co-exist with other communication devices with no discernable interference. This opens vast new communications with providing tremendous wireless bandwidth to ease the growing bandwidth crunch.

However, with transmitting repeated ultra-short pulse signals for the high data rate in the frequency ranges from 3.1 to 10.6 GHz, an analog-to-digital (A/D) converter should operate at very high sampling rate F_s so that UWB communication receiver can implement in a digital domain. In addition, due to FCC emission limitation for the indoor and outdoor operation, the transmitting pulse must be shaped so that the transmitting pulses do not validate the emission limitation. This leads to high requirements for a digital-to-analog (D/A) converter in the UWB transmitter, thereby having a difficult problem to design the A/D converter and the D/A converter with very high-speed for UWB communication transceiver. Moreover, such UWB communication transceiver is not flexibility and scalability for transmitting and receiving pulses if the UWB communication transceiver uses the entire frequency band from 3.1 GHz to 10.6 GHz as one single band operation.

The present invention uses a multiband with a multicarrier solution to form 11 multichannels for the UWB communication transceiver. Each channel has a frequency bandwidth of 650 MHz, which allows transmitting the data rate at 650 Msps. Shaped pulses that meet FCC requirements

of emission limitation for the indoor or outdoor operation can be transmitted on all the channels at the same time. This leads to transmit a total of data rate up to 7.15 Gsps. As a result, the transmitting data rate of the UWB communication device can be flexibility controlled with scalability. Moreover, the sampling frequency rate of A/D and D/A converter can be reduced because of using the multiband solution to substitute a single wideband. In addition, the single UWB communication device of the present invention can deal with a dual-mode indoor and outdoor operation. This leads to saving cost for the UWB communication device.

Thus, there is a continuing need for a multiband UWB communication transceiver with employing dual-mode shaped pulses architecture and polyphase-based multichannel for multicarrier radio for the indoor and outdoor operations.

Summary

In accordance with one aspect, a multiband UWB transmitter may include a polyphase-based multichannel, a shaped pulse generator, and a N-switch in parallel to connect from the polyphase-based multichannel to the shaped pulse generator coupled to a multichannel-based multicarrier modulator.

Other aspects are set forth in the accompanying detailed description and claims.

Brief Description of the Drawings

FIG. 1 shows a block diagram of one embodiment of a multiband UWB communication transceiver for the indoor and outdoor operation.

FIG. 2 is a block diagram of showing a multiband UWB communication transmitter for the indoor and outdoor operation according to some embodiments.

FIG. 3 is a detailed block diagram of a polyphhase-based multichannel and multicarrier of the UWB communication transmitter according to some embodiments.

FIG. 4 is a BPSK modulation relationship between the shaped pulse sequence and the binary symbol sequence according to some embodiments.

FIG. 5 is a two-block diagram of showing polyphase-based serial-to-parallel multichannel according to some embodiments.

FIG. 6 is a QPSK modulation relationship between the shaped pulse sequence and the binary symbol sequence according to some embodiments.

FIG. 7 is shaped digital pulses for the indoor UWB communication transmitter according to some embodiments.

FIG. 8 is a frequency spectrum of the shaped digital pulse for the indoor UWB communication transmitter according to some embodiments.

FIG. 9 is shaped digital pulses for the outdoor UWB communication transmitter according to some embodiments.

FIG. 10 is a frequency response of the shaped digital pulse for the outdoor UWB communication transmitter according to one embodiment.

FIG. 11 is a block diagram of showing two pulse memory banks according to some embodiments.

FIG. 12 is a frequency response of a multiband solution for the indoor UWB communication transmitter according to one embodiment.

FIG. 13 is a frequency response of a multiband solution for the outdoor UWB communication transmitter according to one embodiment.

FIG. 14 is a block diagram of the multiband UWB receiver for the indoor and outdoor operation according to some embodiments.

FIG. 15 is a detailed block diagram of a polyphase-based multichannel and multicarrier down converter for a de-multiband solution UWB receiver according to one embodiment.

FIG. 16 is a detailed block diagram of showing a polyphase-based parallel-to-serial according one embodiment.

Detailed Description

Some embodiments described herein are directed to the multiband UWB communication transceiver for the indoor and outdoor operation. The multiband UWB communication transceiver may be implemented in hardware, such as in an

Application Specific Integrated Circuits (ASIC), digital signal processor, field programmable gate array (FPGA), software, or a combination of hardware and software.

A multiband UWB communication transceiver 100 for indoor and outdoor operation is illustrated in FIG. 1 in accordance with one embodiment of the present invention. The multiband UWB communication transceiver 100 includes low noise amplifier (LNA) and power amplifier (PA) section 114 that receives and transmits multiband UWB signals from an antenna 112 and to an antenna 110. The LNA and PA section 114 is coupled to a UWB multichannel-based multicarrier RF section 116. The UWB multichannel-based multicarrier RF section 116 is connected with an analog and digital interface section of 118 that contains analog-to-digital (A/D) and digital-to-analog (D/A) converters. The analog and digital interface section 118 is coupled to an digital baseband processing section 120, which performs polyphase multichannel digital transmission and receiver filtering, rake processing, shaped pulse generation, interleave/de-interleave, and code/de-code processing. The digital baseband processing section 120 has an interface with a UWB network interface section 122 in which is coupled to a UWB network 124. In accordance with one embodiment of the present invention, the UWB communication transceiver 100 is so-called multiband UWB communication transceiver for the indoor and outdoor operation that can

both transmit and receive speech, audio, images and video and data information for the indoor and outdoor wireless broadband communications.

The multiband UWB communication transceiver 100 can transmit and receive the UWB signals by using one channel and/or up to 11 channels in parallel. Each channel of the UWB communication transceiver 100 has a frequency bandwidth of 650 MHz that can transmit 650 Msps. As a result, the UWB communication transceiver 100 can transmit and receive the data rate up to 7.150 Gsps by using all the channels in parallel.

FIG. 2 is the block diagram of showing a multiband UWB communication transmitter 200 for the indoor and outdoor operation according to some embodiments. The multiband UWB communication transmitter 200 receives user data bits 210 with information data rate at 3575 Mbps. The information data bits 210 are passed through a 1/2-rate convolution encoder 212 that may produce the double data rate of 7150 Msps by adding redundancy bits. The symbol data is then interleaved by using an interleaver 214. Thus, the output symbols of the interleaver 214 are formed 11-multichannel by using a polyphase-based multichannel 216. The symbol data rate of each channel is 650 Msps. The polyphase-based multichannel 216 is to perform a serial data into a parallel data by using the polyphase operation. The polyphase-based multichannel 216 is coupled to a shaped

pulse generator 218 that generates the shaped digital pulse for the polyphase-based multichannel 216 based on the individual symbol. Each shaped digital pulse has a frequency bandwidth of 650 MHz at -10 dBm and -20 dBm for the indoor and outdoor operation, respectively. The output shaped digital pulses of the polyphase-based multichannel 216 are then modulated with multi-carrier frequencies by using a multichannel-based multi-carrier modulator 220. The clock control 222 is used to control the polyphase-based multichannel 216, the shaped pulse generator 218, and the multichannel-based multicarriere modulator 220. Thus, the output shaped pulses of the multichannel-based multi-carrier modulator 220 are passed a power amplifier (PA) 224 through an antenna into air. The entire subsystem section 226 is referred to as the polyphase multichannel-based multicarrier pulse generator.

Referring to FIG. 3 is a detail block diagram of the polyphase multichannel-based multicarrier pulse generator 226 according to some embodiments. The input signal is assumed as x[n], where x[n] is an either "1" or "0" sequence for a serial-to-parallel unit 310, which is a polyphase structure of downsampling by 11. The output of the serial-to-parallel unit 310 contains 11 channels with labels 311a to 311k in parallel operation. Correspondingly, the output signals of the serial-to-parallel unit 310 are x[11n], x[11n-1], …, x[11n-9] and x[11n-10], which are as

the input signals for a set of parallel switch units 320a, 320b, …, 320j, 320k, respectively. A software control unit 390 determines whether a symbol is 1 or 0 for all the channels 311a - 311k. For example, channel 331a, if the signal x[11n] is "1", and then a switch 360a is connected with a position 330a. Thus, a pulse bank 314 that contained an positive indoor shaped digital pulse or an positive outdoor shaped digital pulse is coupled to a D/A converter 318 to generate an analog shaped pulse $y_a(t)$ for the channel 331a. The analog shaped pulse $y_a(t)$ is then multiplied by a carrier function of $\cos(2\pi f_1 t)$ 370a to produce the first bandpass signal for the channel 331a. Otherwise, the switch 360a is connected with a position 330b if the signal x[n] is "0" symbol. A pulse bank 312 that contained a negative indoor shaped digital pulse or a negative outdoor shaped digital pulse is coupled to a D/A converter 316 to generate an analog shaped pulse $y_a(t)$ for the channel 331a. Then, the analog shaped pulse $y_a(t)$ is multiplied by the carrier *function of* $\cos(2\pi f_1 t)$ *370a to produce the first bandpass* signal for the channel 331a. In a similar way, polyphase multichannel-based multicarrier pulse generator 226 generates the analog shaped pulses $y_a(t)$, …, $y_k(t)$ for all of channels 311a to 311k. Thus, the entire analog shaped pulses $y_a(t)$, …, $y_k(t)$ are coherently added together to pass a PA 224 through an antenna into air.

Referring to FIG. 4 is a relationship 400 between a shaped digital pulse sequence and a binary symbol sequence based on a BPSK modulation for the multiband UWB communication transmitter according to some embodiments. A shaped digital pulse 410 represents "1" binary symbol while a shaped digital pulse 420 represents "0" binary symbol. The shaped digital pulse 410 is referred to as "positive" pulse and the shaped digital pulse 420 is referred to as *"negative" pulse. The self-correlation of the shaped* digital pulse 410 and 420 has a positive vale close to "1". On the other hand, the cross-correlation between the shaped digital pulses 410 and 420 has a negative vale close to "-1".

FIG. 5 is a detailed block diagram 500 of showing the polyphase-based serial-to-parallel multichannel based on QPSK for the indoor or outdoor UWB operation according to some embodiments. In the block diagram 550, an input sequence x[n] with either 1 or 0 symbol sequence passes through the serial-to-parallel unit 310 to generate 11 channel sequences 510a-510k. Determining each channel sequence 510a -510k is based on the formula: {x[11n-1], x[11n]}; {x[11n-3], x[11n-2]}; {x[11n-5], x[11n-4]}; {x[11n-7], x[11n-6]}; {x[11n-9], x[11n-8]}; {x[11n-11], x[11n-10]}; {x[11n-13], x[11n-12]}; {x[11n-15], x[11n-14]}; {x[11n-17], x[11n-16]}; {x[11n-19], x[11n-18]}; and {x[11n-21], x[11n-20]}, for n = 0, 2, 4, 6, …, respectively. On

the other hand, using an alternative approach as shown in a block diagram 560 can also do this polyphase-based serial-to-parallel multichannel to achieve the same output as the block diagram 550 does. A switch 530 rotates connecting with one of the eleven positions 540a-540k at uniform speed. For example, the switch 530 is connected to the position 540a for the first channel when n = -1, 0, 21, 22, …. The switch 530 is connected to the position 540b for the second channel when n = -3, -2, 19, 20, …, and so on. During the process, the switch 530 is controlled from the software control unit 390.

FIG. 6 is a QPSK relationship 600 between the shaped digital pulse sequences and the binary symbol sequences based on every two symbols. A positive shaped digital pulse 610a represents two symbols "00". The positive shaped digital pulse 610b, with a delay time Δ, represents two symbols "01". A negative shaped digital pulse 620a represents two symbol "11". The negative shaped digital pulse 620b, with the delay time Δ, represents two symbols "10". This leads to using one shaped digital pulse to substitute two symbols for transmitting a pulse sequence on each channel of the multiband UWB communication transmitter.

Referring to FIG. 7 is impulse responses 700 of the positive indoor shaped digital pulse ($h_{in}[n]$) 710 and the negative indoor shaped digital pulse ($-h_{in}[n]$) 720, with

linear phase. The different between the positive indoor shaped digital pulse 710 and the negative indoor shaped digital pulse 720 is a phase difference. These two shaped digital pulses 710 and 720 are stored into the pulse banks 312 and 314, where are ROM or RAM memory banks. The discrete-time impulse response of the positive indoor shaped digital pulse 710 is listed in Table 3.

Table 3

Pulse taps	Value	Pulse taps	Value
h[0]	8.4011931856093516e-005	h[-20],h[20]	-1.3294520798670319e-006
h[-1],h[1]	6.6460293297797776e-005	h[-21],h[21]	1.5173609022831139e-007
h[-2],h[2]	3.4899656505824461e-005	h[-22],h[22]	1.0025701140610793e-006
h[-3],h[3]	4.3116710798781203e-006	h[-23],h[23]	8.8427894743416094e-007
h[-4],h[4]	-1.1214285545543695e-005	h[-24],h[24]	3.2126248293514667e-007
h[-5],h[5]	-1.1091966005094216e-005	h[-25],h[25]	-1.6257131448705735e-007
h[-6],h[6]	-4.0631985867674594e-006	h[-26],h[26]	-4.2373069355925035e-007
h[-7],h[7]	1.6925543297452028e-006	h[-27],h[27]	-4.9081265774967211e-007
h[-8],h[8]	3.7995683513152043e-006	h[-28],h[28]	-3.2008852157750218e-007
h[-9],h[9]	3.5715207002110990e-006	h[-29],h[29]	7.1976640681523624e-008
h[-10],h[10]	2.1069446071156423e-006	h[-30],h[30]	4.4865425611366231e-007
h[-11],h[11]	-3.6643652826194515e-007	h[-31],h[31]	4.8145760999611724e-007
h[-12],h[12]	-2.8164861523475095e-006	h[-32],h[32]	1.1716686662078990e-007
h[-13],h[13]	-3.3131485713709617e-006	h[-33],h[33]	-3.2175597663148811e-007
h[-14],h[14]	-1.1423931641665744e-006	h[-34],h[34]	-4.3124038368895124e-007
h[-15],h[15]	1.8766255546648780e-006	h[-35],h[35]	-1.5028657655143136e-007
h[-16],h[16]	3.0434874609545600e-006	h[-36],h[36]	2.0356981673707622e-007
h[-17],h[17]	1.5335471709233686e-006	h[-37],h[37]	2.8036698051837603e-007
h[-18],h[18]	-9.2517743205833720e-007	h[-38],h[38]	7.1364948530875849e-008
h[-19],h[19]	-2.0795608829123639e-006	h[-39],h[39]	-1.4582779654249872e-007

Referring to FIG. 8 is a frequency response 800 of the positive and negative indoor shaped digital pulses 710 and 720, respectively, according to some embodiments. The frequency response 800 is symmetric at the center frequency for the use in the indoor UWB operation.

Now referring to FIG. 9 are impulse responses 900 of the positive outdoor shaped digital pulse ($h_{out}[n]$) 910 and the negative outdoor shaped digital pulse ($-h_{out}[n]$) 920, with a linear phase. The different between the outdoor shaped digital pulse 910 and 920 is a 180-degree in phase. These two shaped digital pulses 910 and 920 are stored into the pulse banks 312 and 314, where are ROM or RAM memory banks. The discrete-time impulse response of the positive outdoor shaped digital pulse 910 is listed in Table 4.

Table 4

Pulse Taps	Value	Coefficients	Pulse Taps
h[0]	7.6488735705936605e-005	h[-21],h[21]	-9.9696474129624093e-007
h[-1],h[1]	6.2636205884599369e-005	h[-22],h[22]	6.8001098631267257e-007
h[-2],h[2]	3.8360738472336015e-005	h[-23],h[23]	1.6055470083229580e-006
h[-3],h[3]	1.1315222826039952e-005	h[-24],h[24]	1.3544197859980424e-006
h[-4],h[4]	-7.5438087863256088e-006	h[-25],h[25]	2.8906713844065611e-007
h[-5],h[5]	-1.3715350107903802e-005	h[-26],h[26]	-7.7640460252440758e-007
h[-6],h[6]	-9.6549464333329795e-006	h[-27],h[27]	-1.1590268443143087e-006
h[-7],h[7]	-1.4025569435129311e-006	h[-28],h[28]	-7.2082016980864959e-007
h[-8],h[8]	5.3003810907673923e-006	h[-29],h[29]	1.0449113646872343e-007
h[-9],h[9]	7.2459334117828691e-006	h[-30],h[30]	7.0581527869524552e-007
h[-10],h[10]	4.3825454945279616e-006	h[-31],h[31]	7.2894825863413297e-007
h[-11],h[11]	-7.3762240948801741e-007	h[-32],h[32]	2.7772069871654161e-007
h[-12],h[12]	-4.5458747488001017e-006	h[-33],h[33]	-2.5824128353050490e-007

h[-13],h[13]	-4.7131566336279298e-006	h[-34],h[34]	-5.0913724964550914e-007
h[-14],h[14]	-1.6403017957724223e-006	h[-35],h[35]	-3.7669532172385286e-007
h[-15],h[15]	2.0411082705529443e-006	h[-36],h[36]	-3.2564239303970273e-008
h[-16],h[16]	3.6642171169389545e-006	h[-37],h[37]	2.4370835675220430e-007
h[-17],h[17]	2.4832733363889074e-006	h[-38],h[38]	2.9201867311458947e-007
h[-18],h[18]	-1.2626402560439206e-007	h[-39],h[39]	1.4137476178313894e-007
h[-19],h[19]	-2.1121354877069656e-006	h[-40],h[40]	-5.5504489846808052e-008
h[-20],h[20]	-2.3106300667210457e-006	h[-41],h[41]	-1.7766983155229356e-007

Referring to FIG. 10 is a frequency response 1000 of the outdoor shaped digital pulses 1010 and 1020 according to some embodiments. The frequency response 1010 is symmetric about the center frequency for the use in the outdoor UWB operation.

Referring to FIG. 11 is a detailed block diagram 1100 of showing two memory banks 312 and 314 according to some embodiments. The memory banks of 1120, 1122, 1170 and 1172 are RAMs or ROMs for storing the indoor shaped digital pulses 710 and 720, and the outdoor shaped digital pulses 910 and 920 for the indoor or outdoor UWB operation. The memory bank 1120 contains the positive indoor shaped digital pulse 710 while the memory bank 1170 includes the negative indoor shaped digital pulse 720. The memory bank 1122 consists of the outdoor shaped digital pulse 910 while the memory bank 1172 has the outdoor shaped digital pulse 920. The switches 1124 and 1174 are controlled determining which one of positions should be connected to generate the

shaped digital pulses for BPSK or QPSK based on the indoor or outdoor UWB operation by using the software control 390.

FIG. 12 is an output frequency spectrum 1200 of the polyphase multichannel-based multicarrier pulse generator for the indoor UWB operation, including 11 transmitter channel spectrums 1220A-1220K according to some embodiments. An indoor FCC emission limitation 1210 is also shown in FIG. 12. Each channel frequency bandwidth is 650 MHz and is fitted under the indoor FCC emission limitation 1210 with different carrier frequencies. The detail positions of each transmitter channel spectrums (dBm) along with the center, lower and upper frequencies (GHz) as well as channel frequency bandwidth (MHz) are listed in Table 5.

Table 5

Multichannel Label	Center Frequency (GHz)	Lower Frequency (GHz)	Upper Frequency (GHz)	Frequency Bandwidth (MHz)
1220A	3.45	3.125	3.775	650
1220B	4.10	3.775	4.425	650
1220C	4.75	4.425	5.075	650
1220D	5.40	5.075	5.725	650
1220E	6.05	5.725	6.375	650
1220F	6.70	6.375	7.025	650
1220G	7.35	7.025	7.675	650
1220H	8.00	7.675	8.325	650
1220I	8.65	8.325	8.975	650
1220J	9.30	8.975	9.625	650
1220K	9.95	9.625	10.275	650

FIG. 13 is an output frequency spectrum 1300 of the polyphase multichannel-based multicarrier pulse generator for the outdoor UWB operation, including 11 transmitter channel spectrums 1320A-1320K along with the outdoor FCC emission limitation 1310 according to some embodiments. Each channel frequency bandwidth is 650 MHz and is fitted under the outdoor FCC emission limitation 1310 with different carrier frequencies.

FIG. 14 is a block diagram of the multiband UWB communication receiver 1400 for the indoor and outdoor operation according to some embodiments. A low noise amplifier (LNA) 1410, which is coupled to an automatic gain control (AGC) 1420, receives the UWB signals from an antenna. The output of LNA 1410 is passed through the AGC 1420 to adjust amplitude of UWB signal for a multichannel-based multicarrier down converter 1430. The software and time control 1440 is use to control the AGC 1420 and the multichannel-based multicarrier down converter 1430. The bandlimited UWB analog signals of the output multichannel-based multicarrier down converter 1430 are then sampled and quantized by using an A/D converter 1432, with the sampling frequency rate of 720 MHz. The digital signals of the output of the A/D converter 1432 are filtered by using an indoor or outdoor digital receiver lowpass filter 1434 to remove the out of band signals with controlling from the software and time control 1440. The output data from the

digital receiver lowpass filter 1434 is used for a rake receiver 1436. The channel estimator 1442 is used to estimate a channel phase and frequency that are passed into the rake receiver 1436. The rake receiver 1436 calculates a correlation between the received UWB pulse signals and template pulses, which are provided by using a template pulse generator 1450, and performs coherent combination. The output of the rake receiver 1436 is passed to an equalizer 1444, which also receives the information from the channel estimator 1442, to eliminate inter-symbol interference (ISI), inter-channel interference (ICI), and inter-pulse interference (IPI). Then, the output of the equalizer 1444 passes to a de-interleaver 1446. Thus, the symbol data is de-interleaved by using the de-interleaver 1446. The output data of the de-interleaver 1446 is used for the Viterbi decoder 1448 to decode the encoded data and to produce the information data bits at 3575 Mbps. The entire section unit 1460 is referred to as a polyphase multichannel combiner of the multicarrier down converter.

Referring to FIG. 15, which is a detailed block diagram 1500 of showing one embodiment of the polyphase multichannel combiner of the multicarrier down converter 1460 of the present invention. The received signals r(t) are formed 11 channel signals with labels of 1502a-1502k, with multiplied by carrier frequency functions of $\cos(2\pi f_1 t),\ldots, \cos(2\pi f_{11} t)$, to produce the output signals

$r_1(t)$,…, $r_{11}(t)$ respectively. In parallel, then all the signals $r_1(t)$,…,$r_{11}(t)$ are passed a set of parallel anti-aliasing analog filters 1520a-1520k to have the bandlimited signals for a set of parallel A/D converters 1530a-1530k and digital receiver lowpass filters 1540a-1540k. Then, output signals of the digital receiver filters 1540a-1540k are used for a set of rake receivers 1550a-1550k to perform the correlation measures between the input pulses and the template pulses, which are provided by the template pulse generator 1450. Thus, the output channel signals r[11n+10], …, rs[11n] of the rake receiver 1550a-1550k are combined by using a polyphase upsampling structure to generate the output sequence.

Referring to FIG. 16 is a detailed block diagram 1600 of showing one embodiment of a polyphase-based parallel-to-serial 1560. The input including 11 channels 1620a-1620k in parallel has a length of symbol M. A switch 1630 rotates from a position 1620k to a position 1620a with a uniform speed of every two symbols to produce an output serial sequence with a symbol length of 11M. The software and time control 1440 controls the switch 1630 during the operation. The switch 1630 is adjustable for a uniform speed at a different number of symbols.

While the present inventions have been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and

variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of these present inventions.

What is claimed is:

1